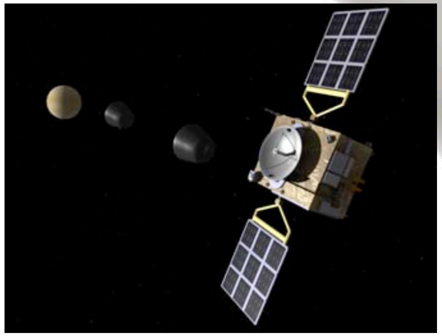
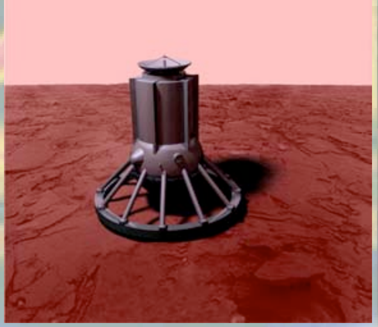
European Venus Explorer : an in-situ mission to Venus using a balloon platform

E. Chassefière (PI), O. Korablev (Co-PI), T. Imamura (Co-PI), K. Baines (Co-PI), C. Wilson (Co-PI), K. Aplin, T. Balint, J. Blamont, C. Cochrane, Cs Ferencz, F. Ferri, M. Gerasimov, J. Leitner, Lopez-Moreno, B. Marty, M. Martynov, S. Pogrebenko, A. Rodin, D. Titov, J. Whiteway, L. Zasova and the EVE team.





Presentation at the 37th COSPAR Scientific Assembly, July 13-20 2008, Montreal, Canada

Why to go to Venus ?

➡ Need for a unified scenario of terrestrial planet formation and evolution

➥ Necessary step toward interpreting future extrasolar Earth-like planet observations

➥ Venus : a key to our understanding of habitability and potential for life on Earth-like planets

Strong need for an in situ mission to understand the evolution and climate of Venus

Why EVE?

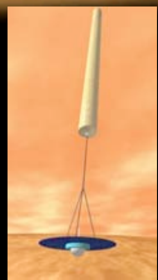
In situ measurements needed for many purposes e.g. :

- Isotopic ratios of noble gases,
- Cloud/lower atmosphere chemistry cycles…

How?

Orbiter
(2 years)

Balloon
(7 days)



JAXA balloon (optional)

Descent probe
(1h30)

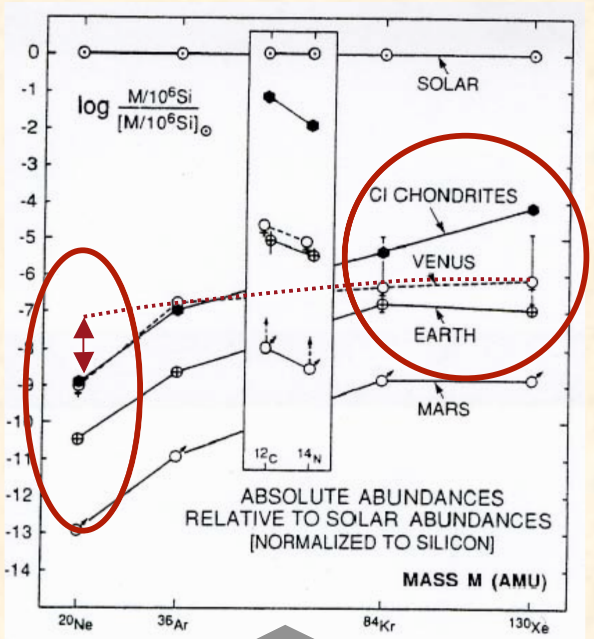
With which goals?

- Unified model of the formation and evolution of terrestrial planets
- Stability of the current climate
- Chemical/radiative processes in and below the clouds
- Geological history of Venus
- Atmospheric dynamics
- Electrical processes

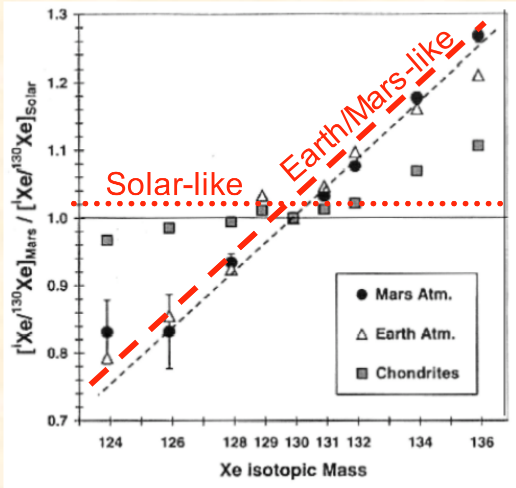
Baseline science return : evolution

In situ measurement from the balloon of noble gas abundances and stable isotope ratios, to study the record of the evolution of Venus.

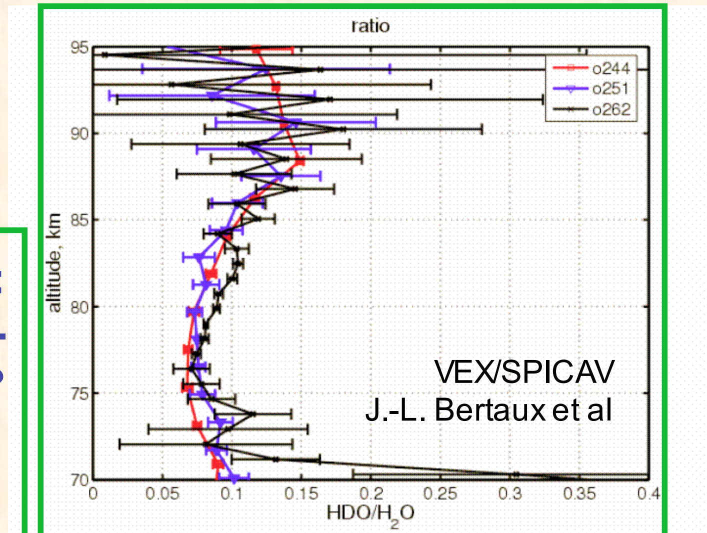
From Pepin and Porcelli, 2002



→ Venus isotopic ratios : Earth/Mars-like or solar-like?



→ Elemental ratios : Kr, Xe Earth/Mars-like, solar-like or chondritic-like? Why is Ne depleted?



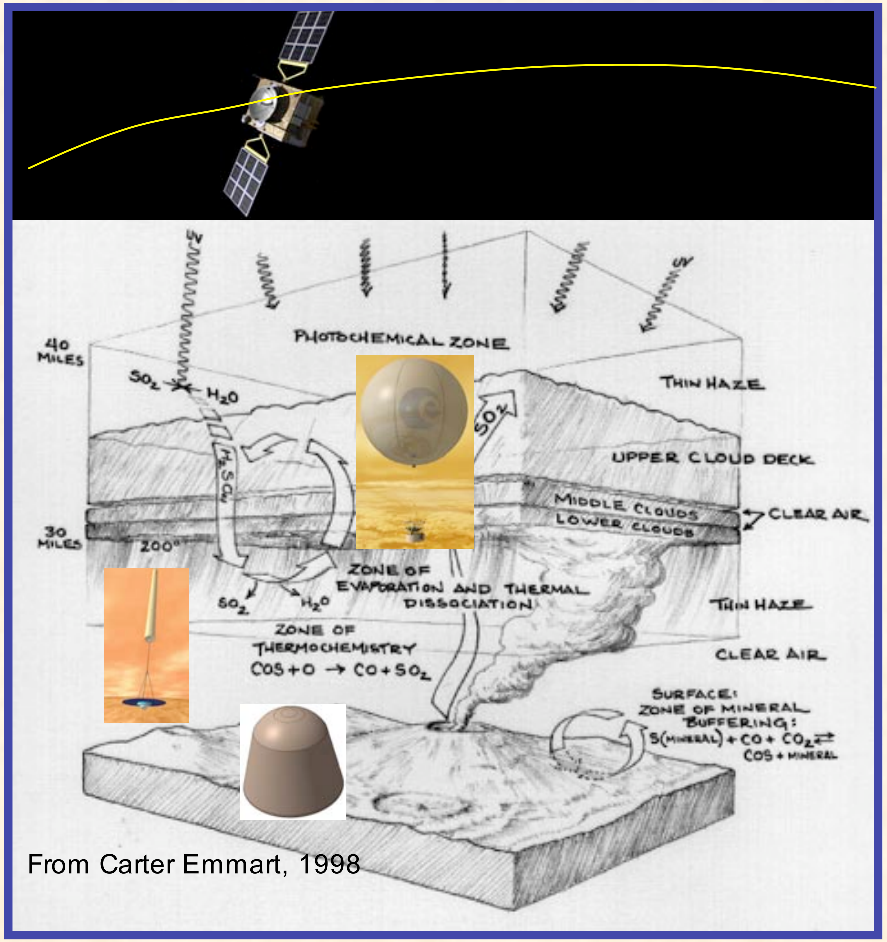
→ D/H profile to be measured in and below the clouds

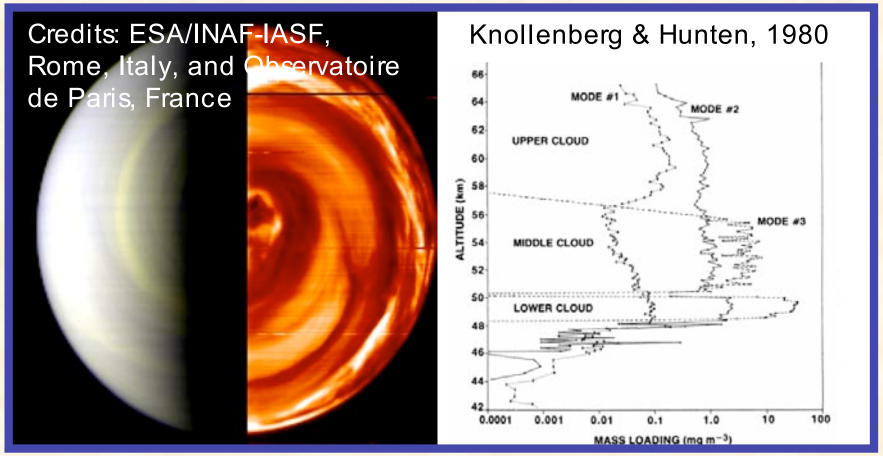
→ S isotopes : nothing known (to be measured vs altitude/ time)

→ N and other isotopes : accuracy to be improved

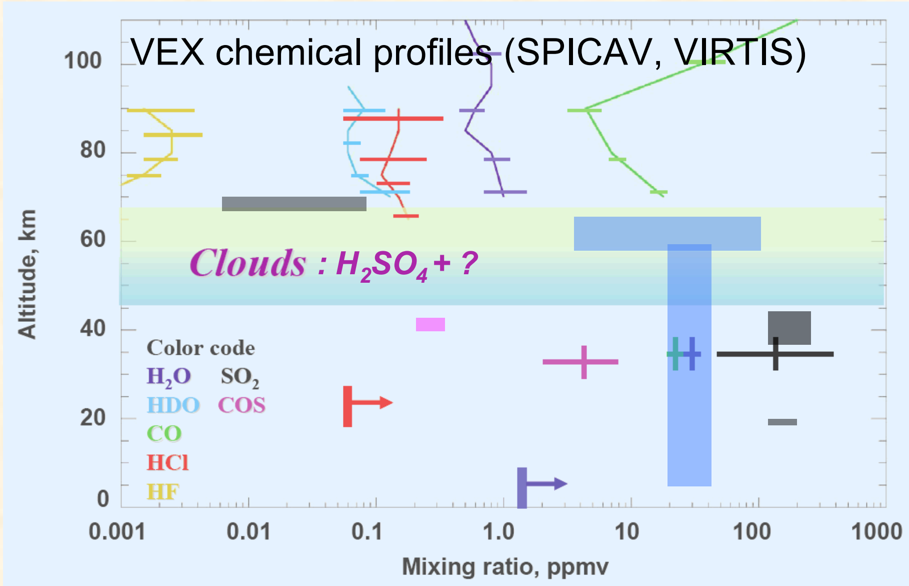
Baseline science return: chemistry

In situ balloon-borne measurements of cloud particle and gas composition, and their spatial variation, to understand the complex cloud-level chemistry.



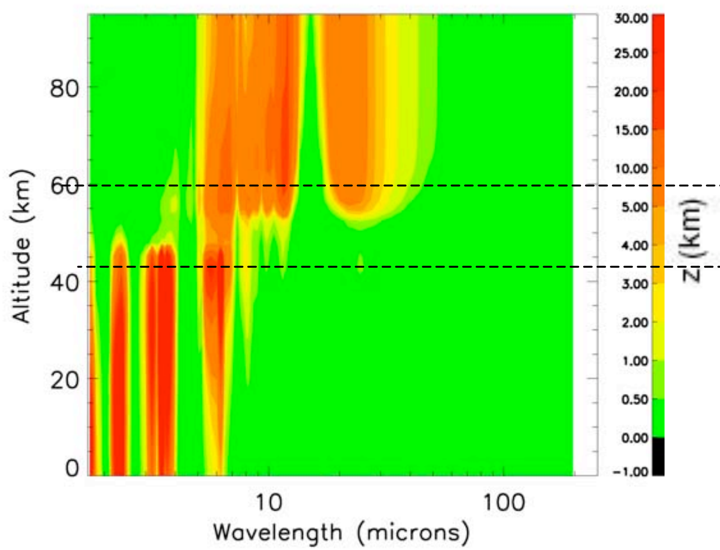


Horizontal/vertical variability of deep clouds :
strong need for sampling at different locations

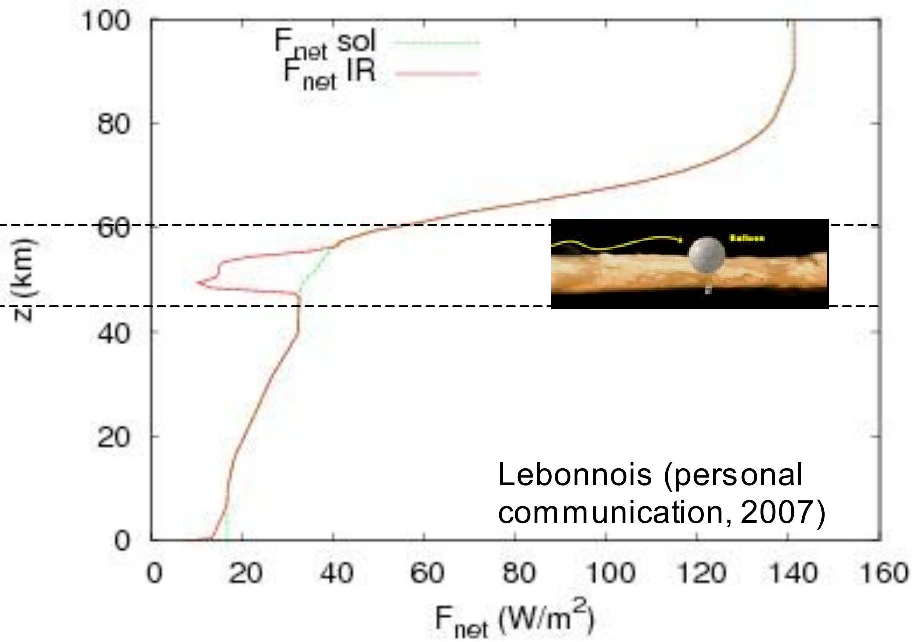


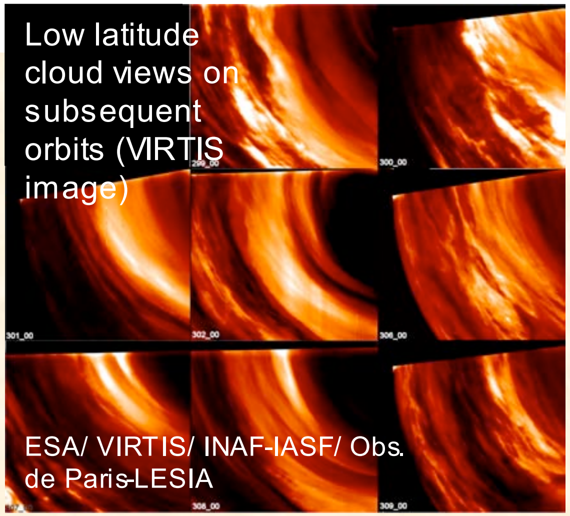
Baseline science return: radiative balance and dynamics

Upward radiative flux (LMD GCM)



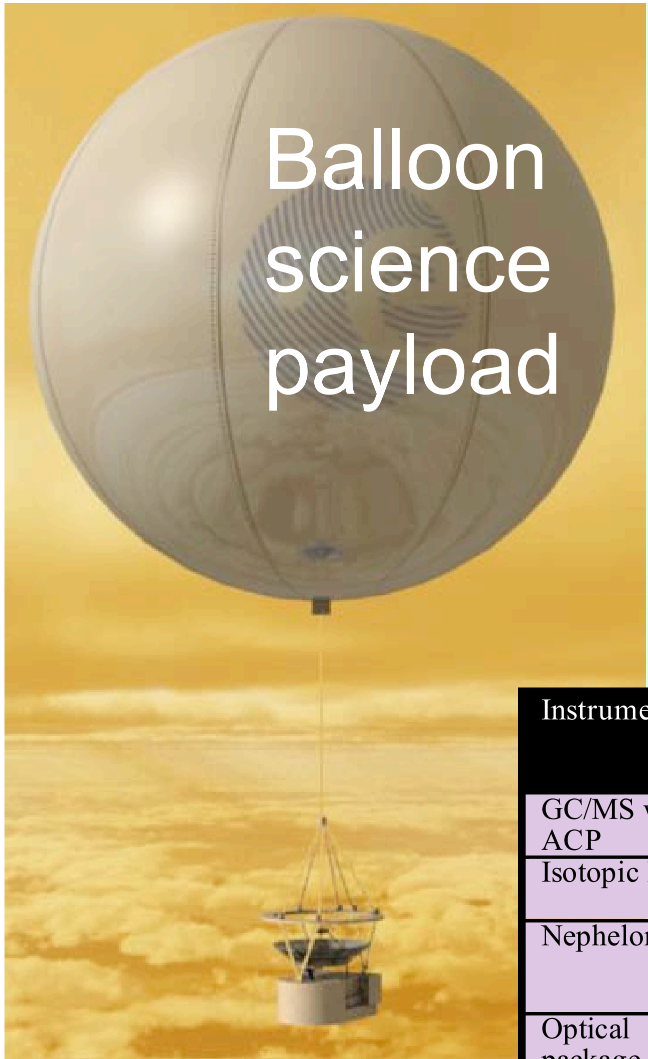
Net IR and visible radiative fluxes (LMD GCM)





In situ measurements of environmental parameters and winds (from tracking of the balloon) for one rotation around the planet (7 days), to understand atmospheric dynamics and radiative balance in this crucial region.

Balloon science payload

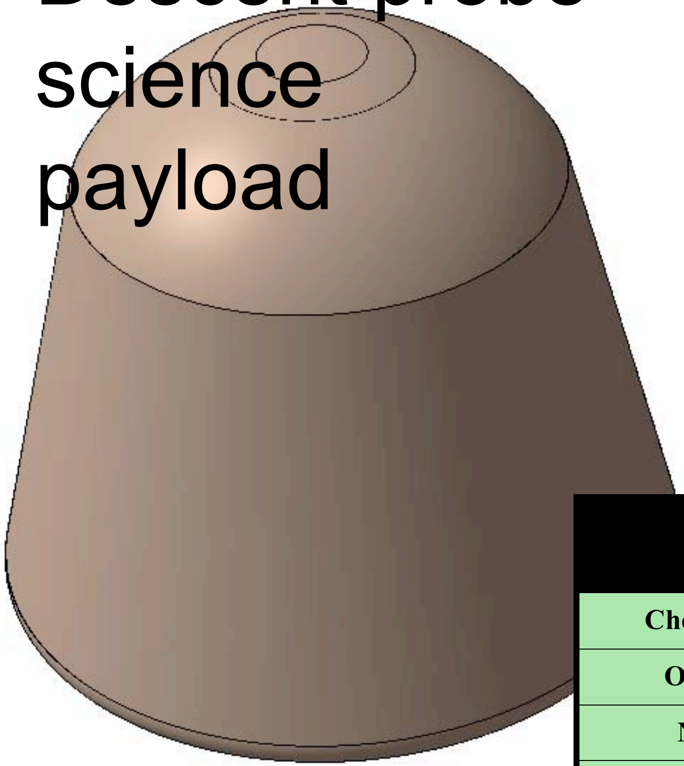


- Composition of atmosphere and aerosol particles
- Microphysical properties of aerosol particles
- Isotopic ratios of noble gases, and of light elements
- Local wind velocity from tracking the balloon's position
- Upwards and downwards fluxes of radiation
- Electrical properties of atmosphere and clouds
- Cloud particles for exobiological potential
- Vertical profiles of radiative fluxes, pressure, temperature, and chemical abundances

Instrument	Mass (kg)	Power (W)	Data rate (bps)	TRL Level/ heritage	Potential provider (laboratory, consortium)
GC/MS with ACP	3.6	15W (peak)	30	4/5, Huygens, MSL, ExoMars, Phobos	IPSL (France), Open University (UK), IKI (Russia), others.
Isotopic MS	4.0	15W (peak)	11.6	4/5, Beagle2, Rosetta	Open Univ (UK) / IPSL (Fr) / U. Berne (CH)
Nephelometer	1.0	2 W	1.4	3-4	NASA-led (Cornell/Ball Aerospace) with TU Delft. Other possibility: IKI
Optical package	0.5	1.2 W	1.6	4	Univ. Oxford (UK)
Atmospheric package (p, T, acc, sound)	0.4	2 W	0.4	5 Huygens, Beagle 2, ExoMars	FMI (Finland) / Oxford U & Open U (UK) / Padova (Italy) / IAA (Spain) / IWF (Austria)
VLBI beacon / USO	0.5	5 W	0.8	8	CNES (France) / TBD JIVE (NL) – Ground Segment
Electrical / EM package	0.4	2.5 W (peak)	10.0	6 Compass-2, ISS	Eötvös Univ (Hungary) & RAL (UK)
ATR spectrometer	2	5 W (peak)	5	4	IKI (with IFSI participation)
TOTAL	12.4 kg w/o margin; or **15 kg including 21% margin**				

Heritage : Huygens, Exomars…

Descent probe science payload



- Composition of atmosphere and aerosol particles vs altitude
- Isotopic ratios of major molecules vs altitude
- Microphysical properties of aerosols
- Atmospheric structure and wind during descent
- Radiative fluxes
- Imaging of the surface during descent and after landing
- Composition of the surface
- Electrical properties of atmosphere

Instrument	Mass (kg)	Power (W)	Data rate (bit/s)	TRL (2007)	Origin
Chemistry package	3.7	<20 W	3	4-8	IKI, IPSL, MPS, UK
Optical package	1.5	6 W	1.6	4	IKI, IPSL
Nephelometer	1	2 W	1.4	4	IKI, Inst Appl. Math.
Imaging system	0.7	3W	3+	6	IKI
ATR spectrometer	2	5 W	5	4	IKI, IFSI
Accelerometer	0.2	1 W	0.3	8	IKI, TSNIIMASH
Meteorological package	0.3	2 W	0.4	5-7	IKI/ FMI
Gamma-spectrometer	8	17W	2	6-8	IKI
Lightning detector	0.8	2.3W	0.5	6	IKI, Eötvös Univ
OBDH	1.7	5W	-	7	IKI
20% Margin	4				
Budget:	**23.9 kg**				Russia, EU

Heritage : Vega, Phobos, BepiColombo…

Orbiter science payload

- Escape fluxes
- Auroras
- Wind field
- Atmospheric composition
- Temperature profiles
- Electrical/ electromagnetic activity
- Cloud structure
- Subsurface structure

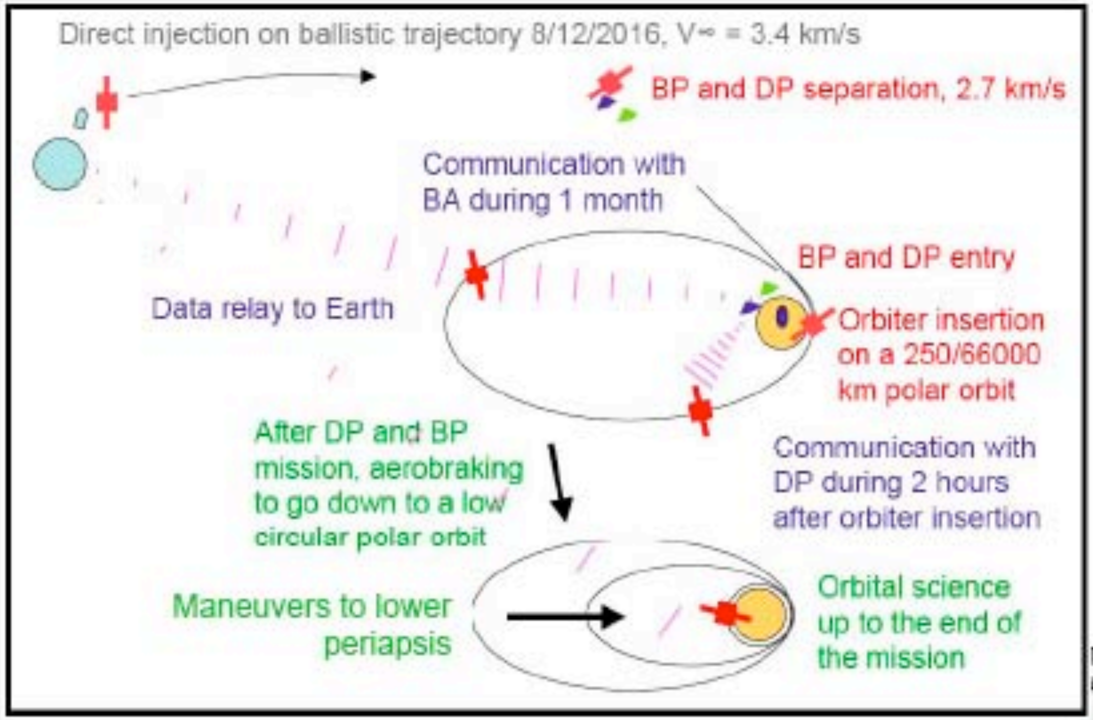
Instrument	Mass (kg)	Power (W)	Data rate (kbps)	TRL Level/ heritage	Potential provider (laboratory, consortium)
Neutral mass spec.	3	4	~ 1	4, Giotto, Cassini, BepiColombo	IPSL (France)
Ion mass spec.	1.5	3-7	~ 2 (≥0.02)	4, BepiColombo	Consortium: IKI (Russia), Mullard (UK)
UV plasma imager	2.3	5	6	6, Nozomi, BepiColombo	Tohoku Univ. (Japan)
Sub-mm sounder	9.2	40	~ 9.2	8/9, Rosetta, Herschel	Max Planck Institute (Germany)
UV mapping spectrometer	1.5	5	40	9, MEX	Consortium: INAF (Italy), IKI (Russia)
Lidar (TBC)	7.4	70	4.8	4/9, Phoenix Mars	York Univ., MDA, CSA (Canada)
Infrared Spectrometer	2.4	7	4.4	5, Mars Express, Venus Express	Consortium: IKI (Russia), INAF (Italy)
High-speed / context camera	3.5	10	< 10	6, ground based	Greman Aerospace Center (Germany)
USO for radio science	1	1	0	9, in most of missions	e.g General Dynamics (UK)
EM Wave analyser	0.7	4-4.5	~ 4	7/5, Compass-2, ISS,… sw. BepiColombo	Consortium: Eötvös Univ., BL Electronics (Hungary)
Subsurface Radar	7.2	9	≤ 80	7/8, MEX, MRO and ExoMars	Consortium: IPG, Obs. Midi-Pyrénées & de Bordeaux (France), GSFC, JPL and UTA (USA)
Magneto-meter	≤ 1.2	1.2	1.5	9, Oersted, Champ, Proba-2, Swarm …	Dan. Nat. Space Center (Danemark), Imperial College London (UK)
Gamma Flash Detector	2.3	3	10	7/5, Coronas-F	Consortium: IKI, SINP MSU (Russia)
20% margin	8.6				
Total :	**51.8**	**≤ 170**	**210**	**-**	**ESA (& ECS), Russia, USA, Japan, *Canada***

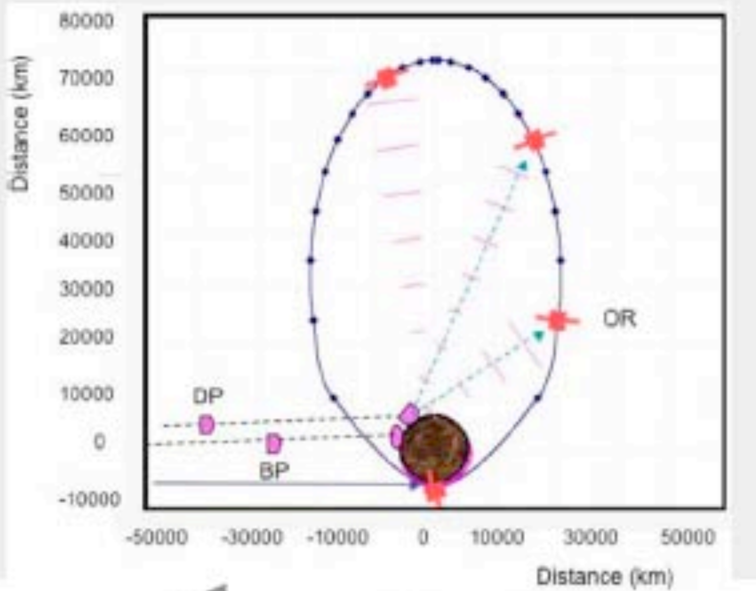
Context science for probes

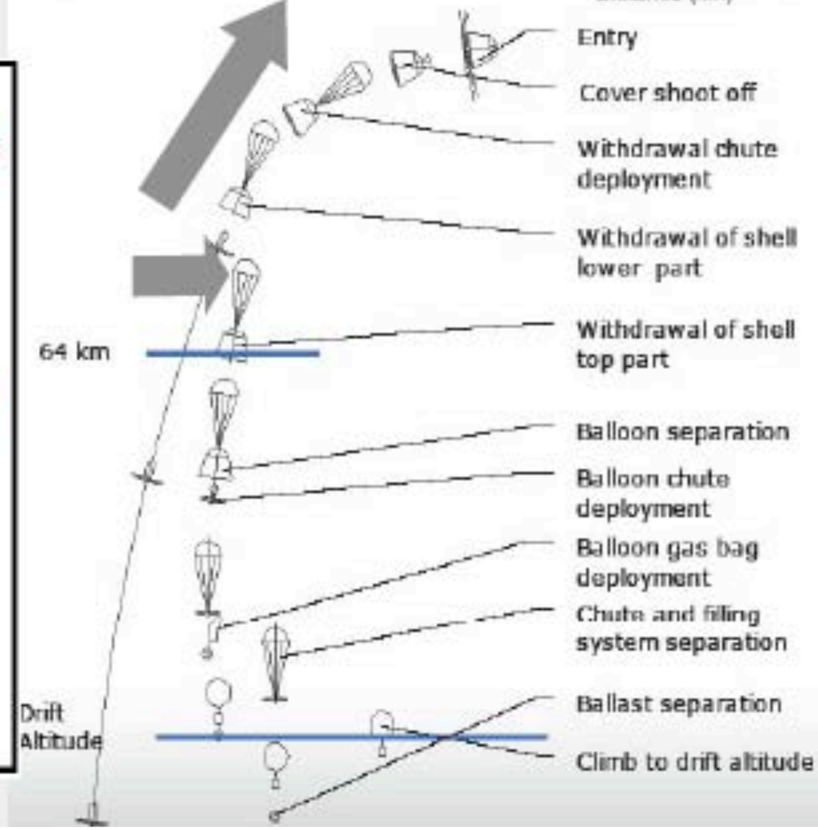
Mostly new orbital payload

Mission baseline

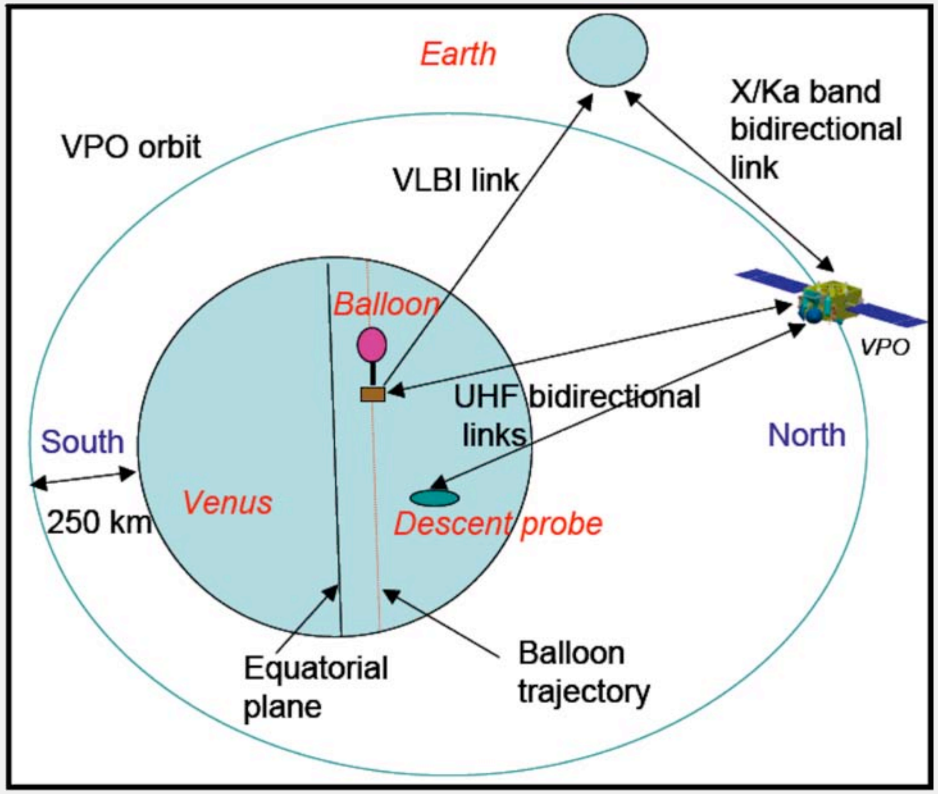
	2016 (nominal)	2018 (backup)
Departure date	8.12.2016	10.06.2018
Departure conditions	$v_\infty = 3.38$km/s $\delta_\infty = 32$deg	$v_\infty = 3.93$km/s $\delta_\infty = -39$deg
Arrival date	18.05.2017	11.12.2018
Arrival relative velocity	2.68 km/s	2.99 km/s
Cruise duration	161 days	184 days

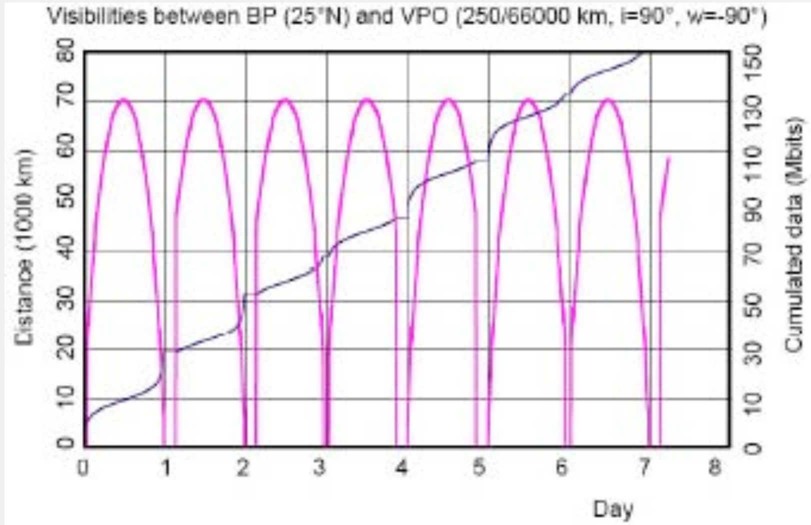






Telecommunication strategy





Aver. balloon data rate : ≈200 bps

	Westbrock	*Effelsberg*	*Green Bank*	*Medicina (Northern Cross)*	*Arecibo*	*SKA=30%*
Aperture	14 x 25m	100 m	100 m	30,000 m^2	300 m	300,000 m^2
Frequency range (MHz)	300-450	350-450	300-500	406-410	425-435	300-500
Aperture efficiency	0.35	0.6	0.6	0.4	0.4	0.4
SNR (in 1Hz)	35	110	270	230	1100	3500
Max. data rate (bps)	20	65	150	130	600	2000
Aver. Data rate (bps)	≈2	≈7	≈20	≈15	<≈30	≈200
TRL (2007)	8	8	8	8	8	3

Data rate achievable by UHF transmission from balloon (or descent probe) direct to Earth

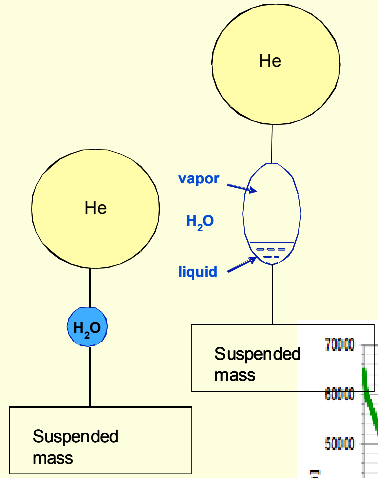
Balloon probe

Heritage : Superpressure balloon

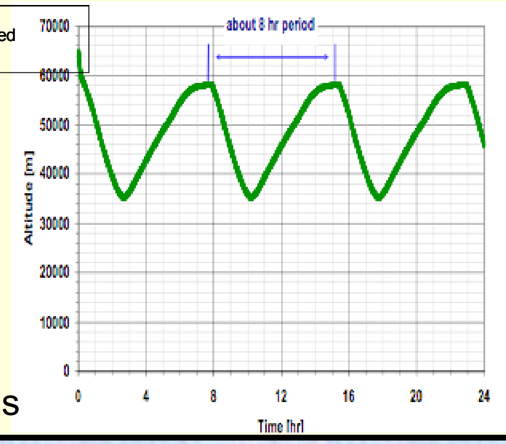
CNES Venera superpressure balloon (1970–1980) : 9 m Φ, fully developed, tested and space qualified

The EVE 5 m Φ balloon, twice smaller, is therefore fully proved (technically behind us!)

Preferred option for EVE : Phase change oscillating balloon



Enhancement of science return wrt superpressure balloon



CNES calculations

Sub system	Mass (kg)	Comments
Gondola	40	Includes 15 kg of scientific instruments
Balloon	17	Includes 10 kg of envelop and 7 kg of He
Gas storage system	23	Based on He gas tank.
Russian Entry System	90	Parachute, inner structure, back cover
Total	170	

International cooperative scheme

170 Co-Is from 70 laboratories

18 countries including Russia, Japan, USA and Canada

- EUROPE
  - The spacecraft,
  - the balloon platform,
  - the Kourou element of the launch costs and
  - the science payload under national contribution.
- RUSSIA
  - The dry Soyuz launcher,
  - the descent probe,
  - the entry/descent systems for both balloon and descent probe and
  - a contribution to the science payload and data analysis.
- JAPAN
  - A small balloon for low altitude studies (option),
  - A ionospheric UV imager
- USA & CANADA
  - Comprehensive science and instrument hardware involvements and
  - the possibility of using NASA/JPL developed Venus balloon technology through international collaboration, under NASA's Mission of Opportunity (MoO) program.

Key technologies

- Orbiter :
  - Thermal control : Vex/Bepi heritages
  - Aerobraking : used 4 times by NASA
- Descent probe/ entry-descent system for balloon:
  - Systems : Venera/Vega heritages
  - Instruments : Vega, Huygens, BepiColombo, etc heritage
- Balloon
  - Envelope and inflation system (CNES) : Vega heritage
  - Gondola (ESA) : instruments mature, cells, batteries, DPU at TRL 3 to 5 (cf ESA VEP TRS study)
  - Descent-entry system (Roscosmos) : Venera heritage

- NO TECHNICAL SHOW-STOPPER IDENTIFIED
- MULTIPLE AND STRONG HERITAGES
- POWERFUL MINIATURIZED IN-SITU INSTRUMENTS (EXOMARS, MSL, …)

Result of Cosmic Vision selection process

- EVE has not been selected by ESA SSWG,
- but it has been highly ranked scientifically :

"The European Venus Explorer (EVE) was seen by the SSWG as an attractive mission which was highly ranked scientifically. However, programmatically (with three ESA mission programmes currently operating or in implementation at terrestrial planets) the SSWG considered selection at this stage premature."

- What are the news, and next steps?

• EVE is a « Science Theme » of the ESA Cosmic Vision Technology Development Plan

• Several phase A studies for the EVE balloon are recommended by ESA (under national funding)

• Second workshop "Earth and Space Sciences in Europe using CNES Balloons », September 2008, Pau, France.

• Venus Flagship mission under definition at NASA : balloons + descent probes + orbiter (2020-2025)